

Perspectives of IXO follow-up of eROSITA AGN

Marcella Brusa (MPE)

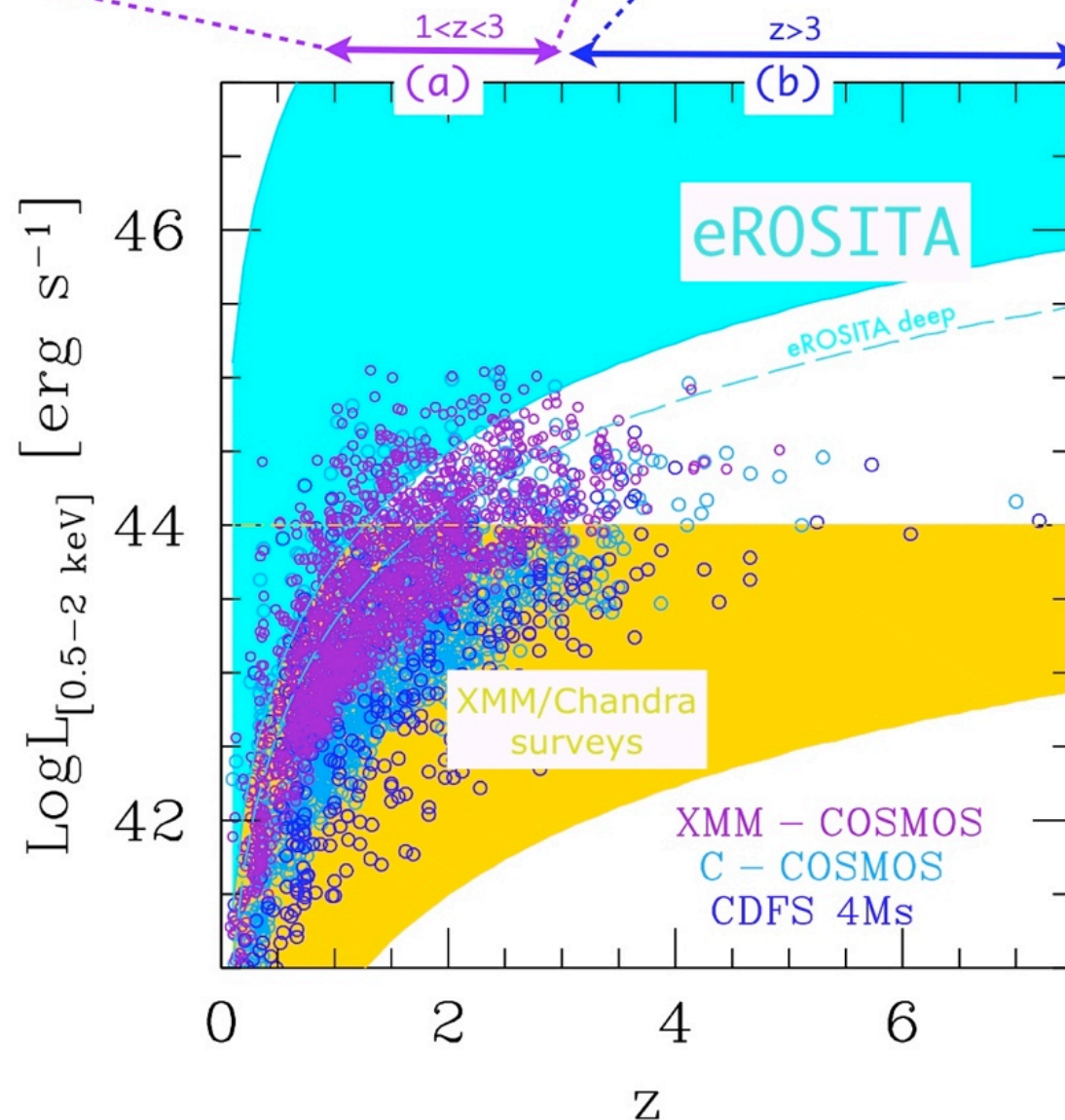
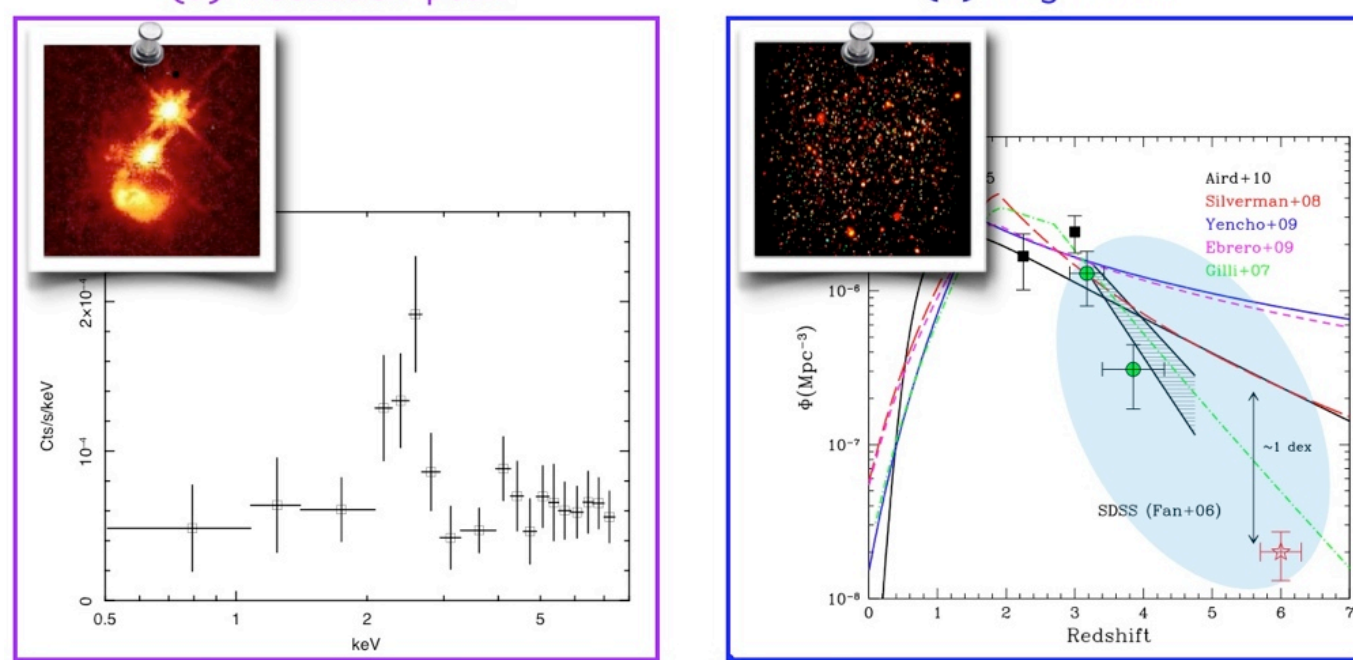
with help from: **Pooja Chaudhary, Davide Burlon**

Nico Cappelluti, Andrea Merloni, Hermann Brunner, Angela Bongiorno

eROSITA

2 main AGN topics

(see Merloni's talk)



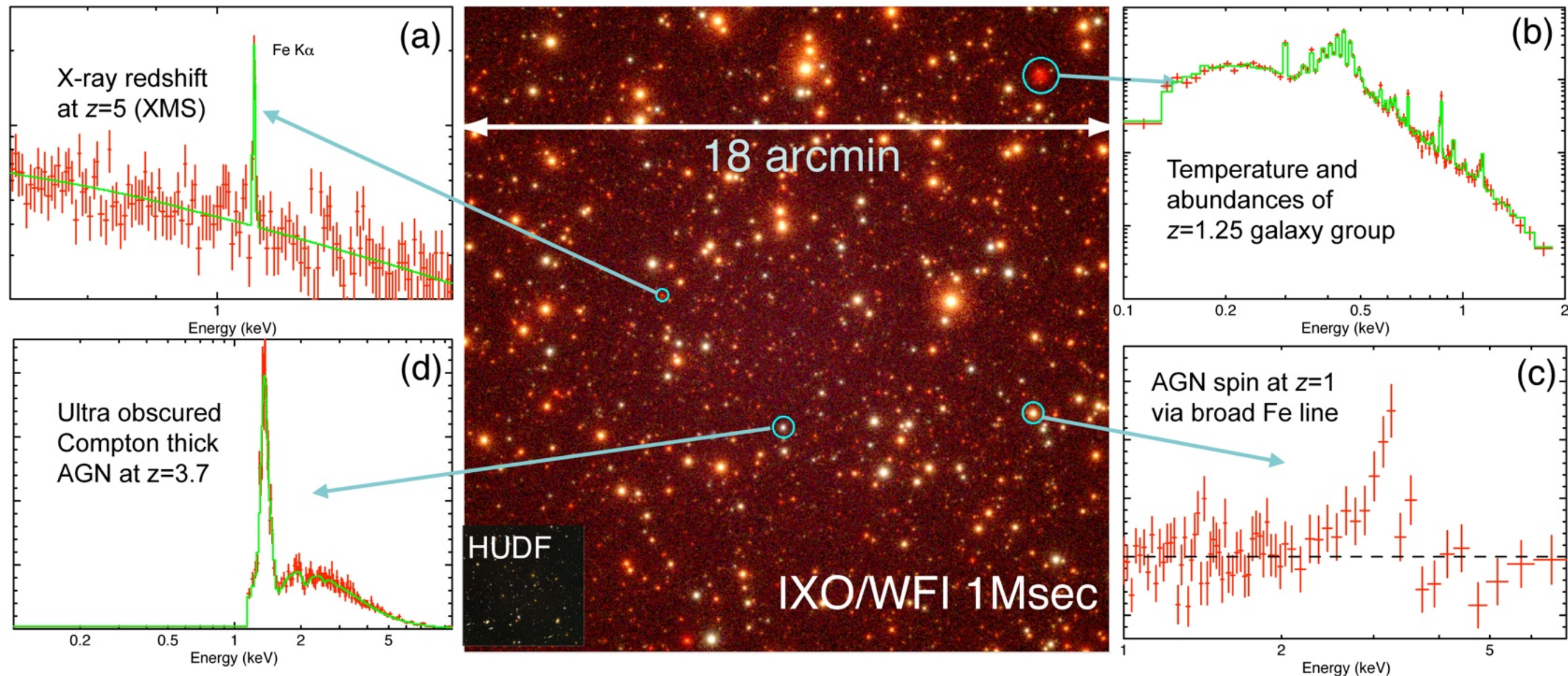
1) first sizable sample of **X-ray selected $z > 6$ AGN**, i.e. first accreting BHs (see Gilli's talk)

2) bright hard **X-ray selected QSO2 samples at $z=1-3$** , i.e. signposts of major events in galaxy-AGN coevolution (see Maiolino/Feruglio's talk)

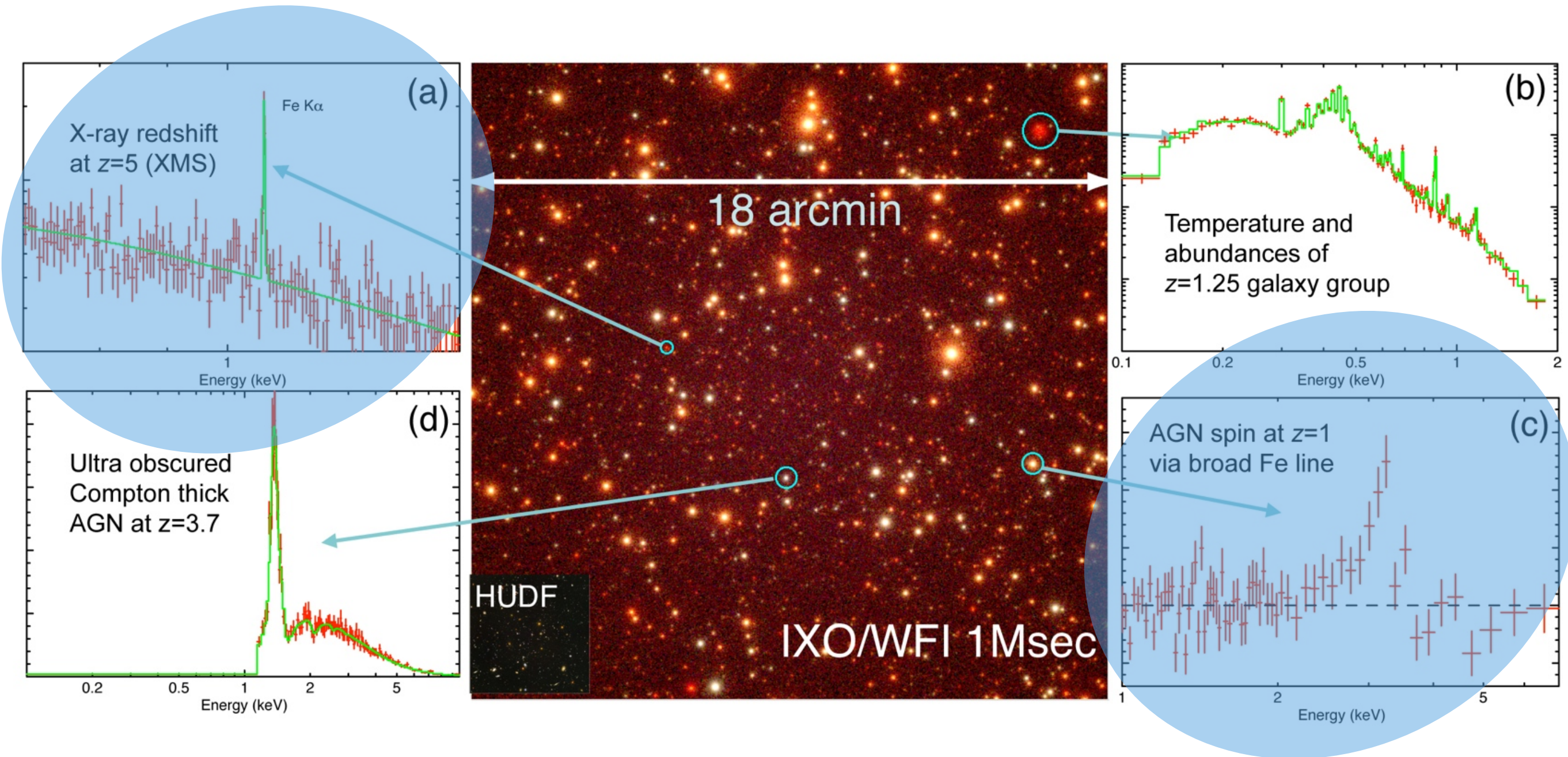
rare objects!

eROSITA key feature: AREA

IXO - matter under extreme conditions



IXO - matter under extreme conditions



Spectroscopy of high- z and obscured AGN up to the highest- z also key goals of IXO “matter under extreme conditions” & “the violent, evolving universe” science topics

Why IXO follow-up?

IXO can provide

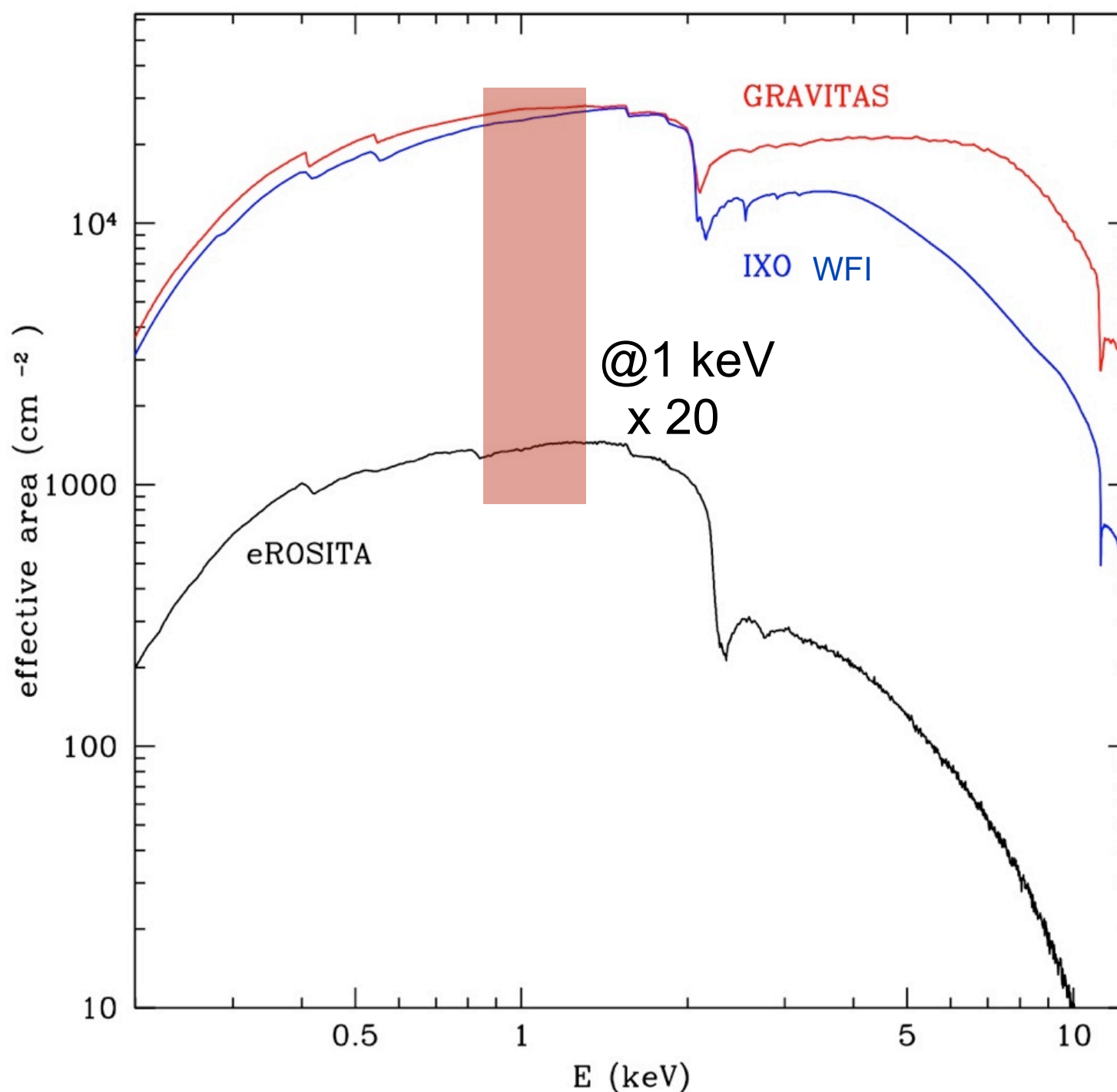
UNIQUE spectral characterization (absorption, outflows, spin) of well defined/selected samples of eROSITA sources detected with low-counts

But, please note:

- **numbers** may not be the final ones (background level, conversion factors, selections, actual instruments performance etc.), plus model predictions maybe not correct --> **please take home “order of magnitudes” estimates!**

- eROSITA **deep observations strategy not yet fixed/finalized** (area and exposure) --> all considerations are done for the all-sky survey

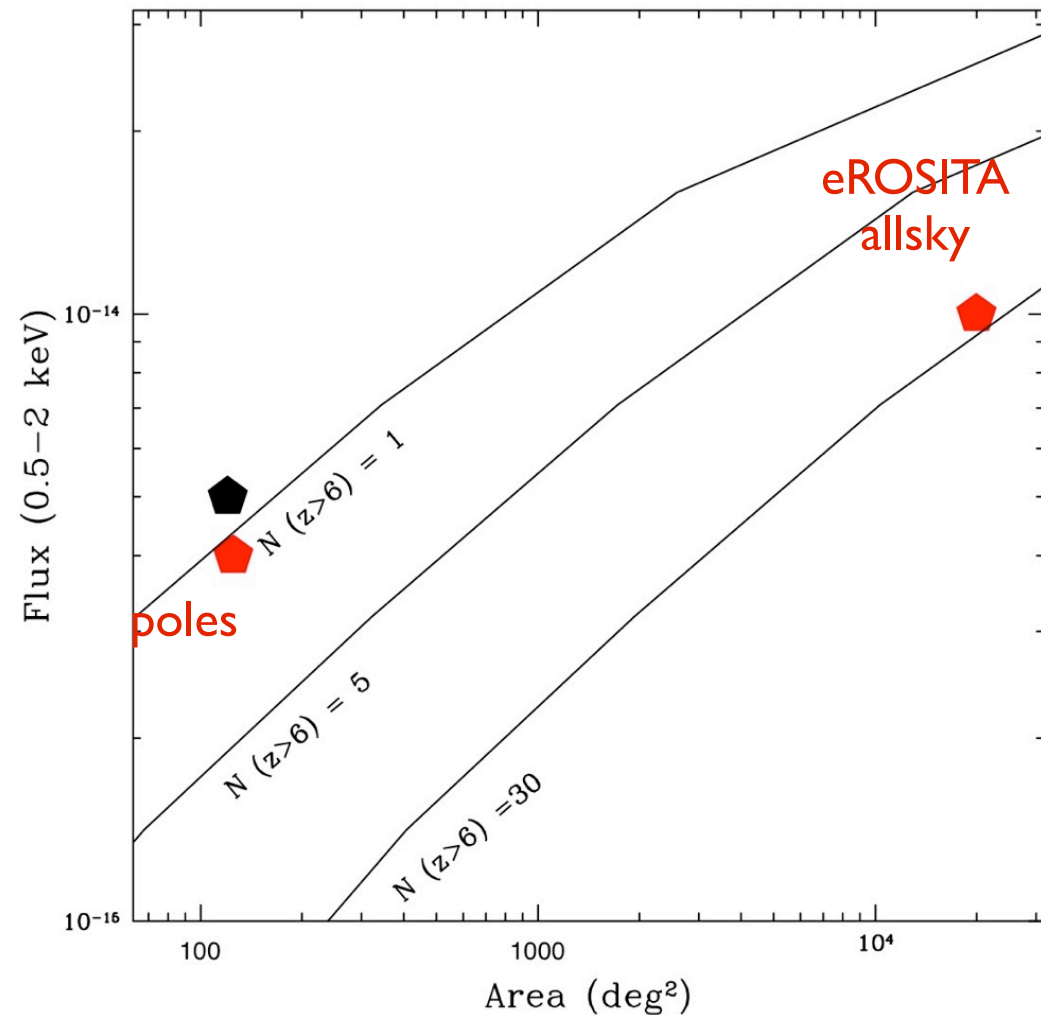
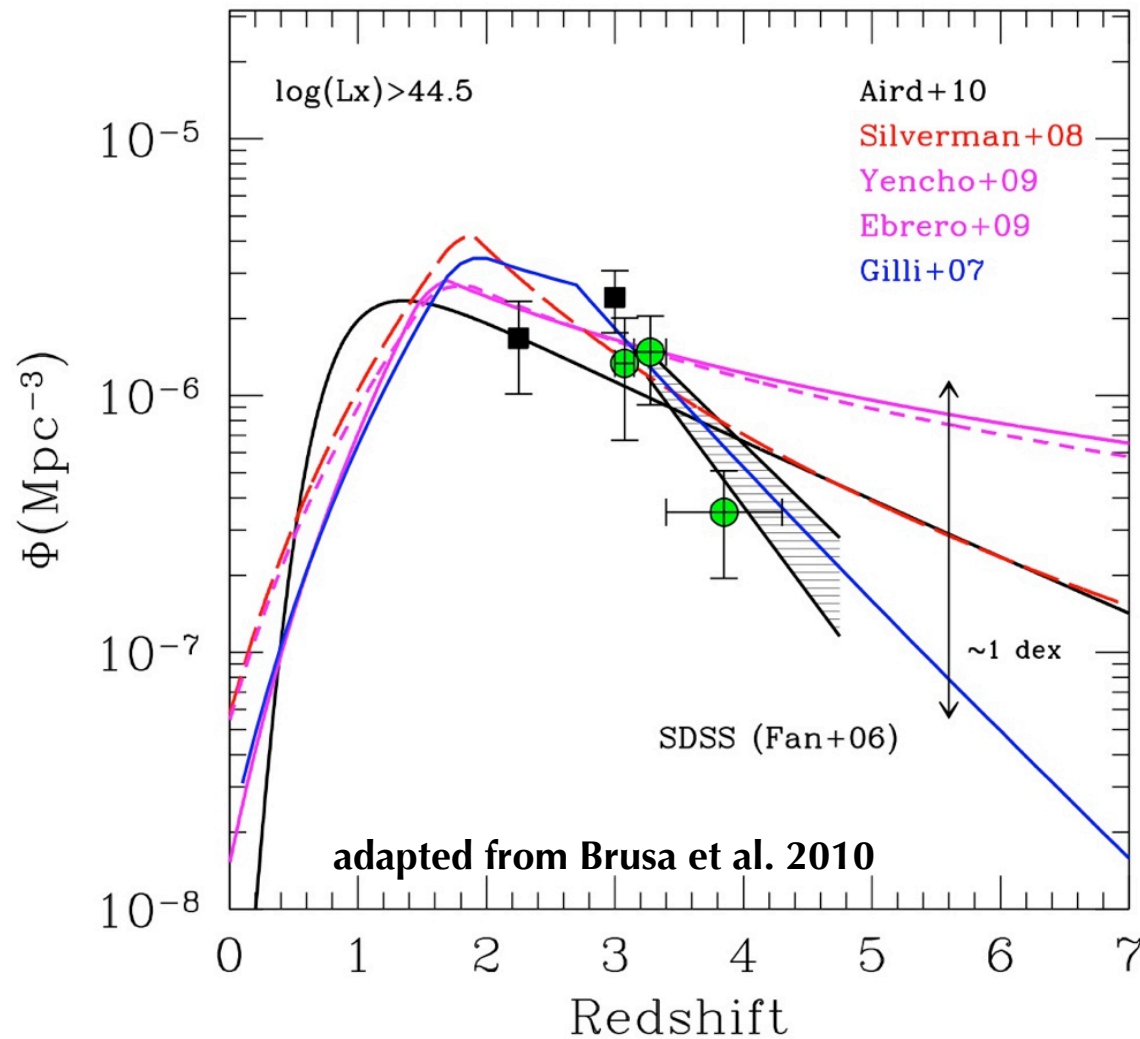
Effective areas: IXO vs. eROSITA



best synergy strategy : eROSITA to preselect, IXO to follow-up

High- z ($z>6$) AGN

(see also Gilli's talk)



PREDICTIONS for eROSITA survey:

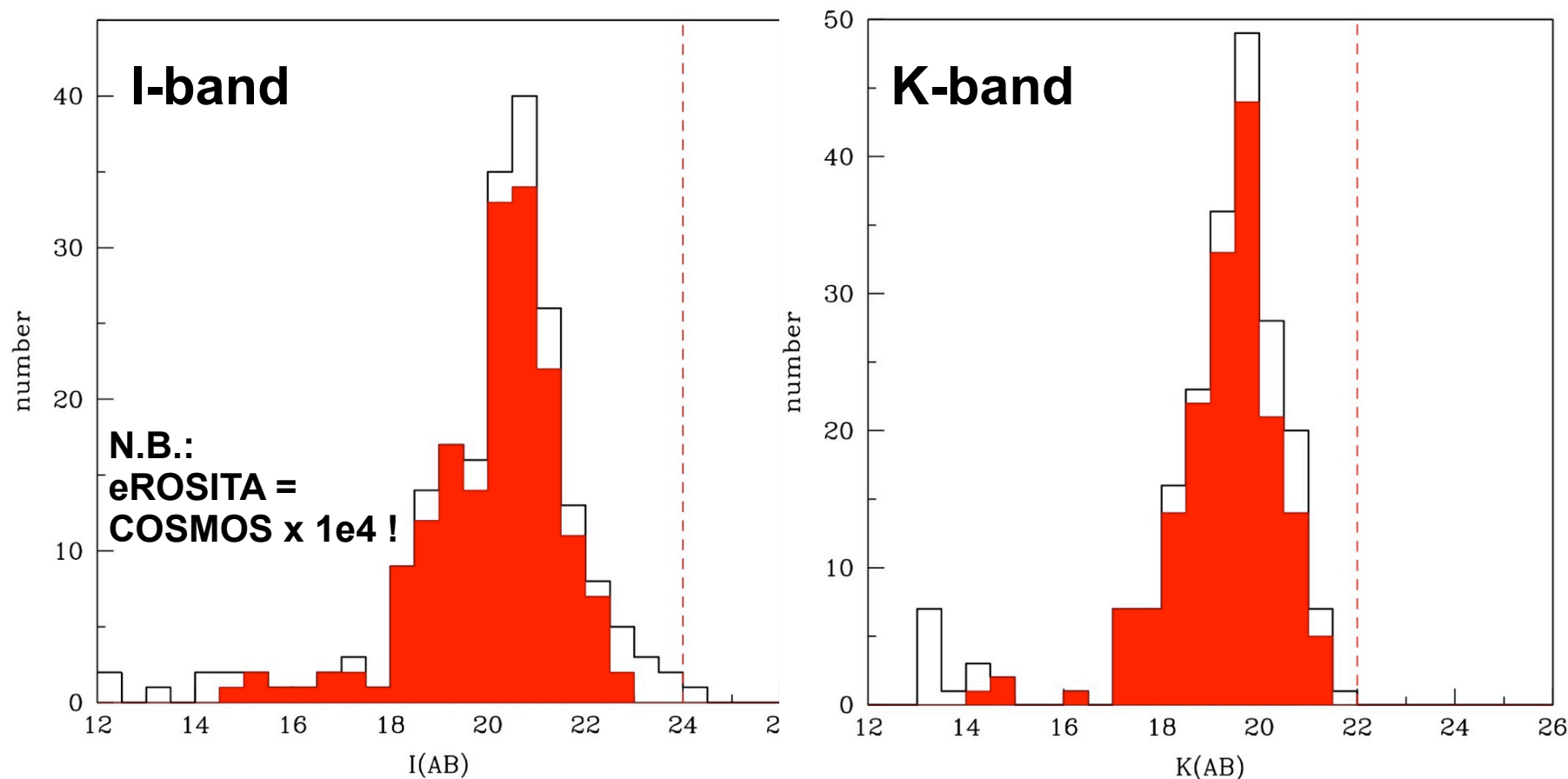
- 1) assuming a limiting flux of $\sim 10^{-14}$ cgs in the soft band
- 2) using Gilli+2007 model (with decline model, e.g. Brusa+2009) <http://www.bo.astro.it/~gilli/counts.html>

~30 (lower limit) over the entire sky at **$\log L_x > 45$** erg/s (N.B. **ZERO** X-ray selected $z>6$ AGN in the XMM/Chandra/ROSAT samples; ~ 20 from optical surveys, SDSS & CFHT Fan et al. 2006, Jiang et al. 2009, Willott et al. 2009)

N.B. **>20.000** $z>3$ QSOs expected in eROSITA !!

Sensitivity needed & future large area surveys

XMM-COSMOS 0.5-2 keV sources at $F > 1e-14$



adapted from Brusa et al. 2010, ApJ
[see also Brusa et al. 2010, WFXT
White Book, arXiv:1008.1914]

**Sensitivity of the order
of $I \sim 24$ and $K \sim 22$ needed
on the all sky
(identifications problems may affect
5-10% of the sources)**

Key resources (existing and foreseen):

PanSTARRS: $I \sim 24.2$ (+grzy)

DES: $R \sim 24$ (rgizY)

LSST: $I \sim 25.5$ (+ugrzy)

SDSS-III (BOSS) (large FOV, large # fibers)

4MOST (new dedicated spectrograph @ESO):
for efficient spectroscopic follow up

VISTA/VHS: $K \sim 20-21$ (+HJY) (60-80% of the cp)

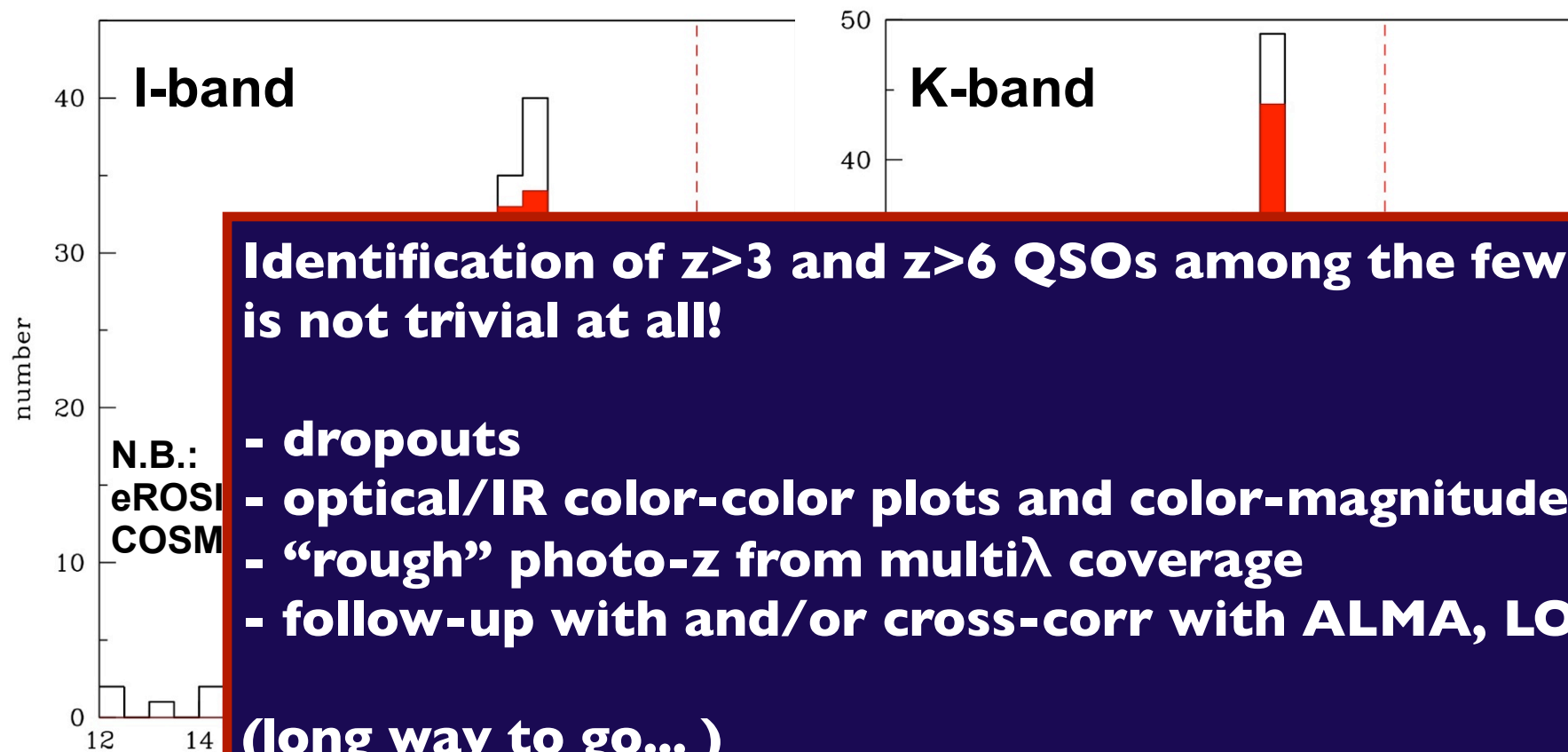
EUCLID: $K \sim 23.5$ (+zJH)

WISE: 3.6~19.5 (not enough?)

LOFAR: 0.8 mJy at 120 MHz (= 0.1 mJy at 1.4 GHz)
“radio” emitters (AGN and starburst)

Sensitivity needed & future large area surveys

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Identification of $z > 3$ and $z > 6$ QSOs among the few million eROSITA AGN is not trivial at all!

- dropouts
- optical/IR color-color plots and color-magnitudes diagrams
- “rough” photo- z from multi λ coverage
- follow-up with and/or cross-corr with ALMA, LOFAR, JWST samples

(long way to go...)

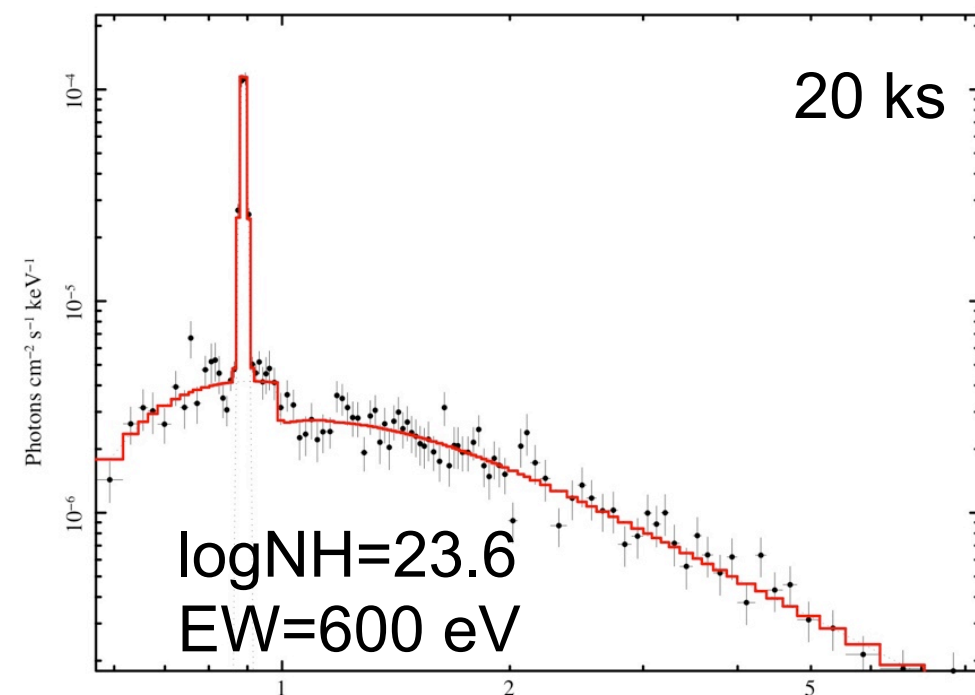
other lambda information is mandatory, but X-ray detection is the fingerprint of accretion!

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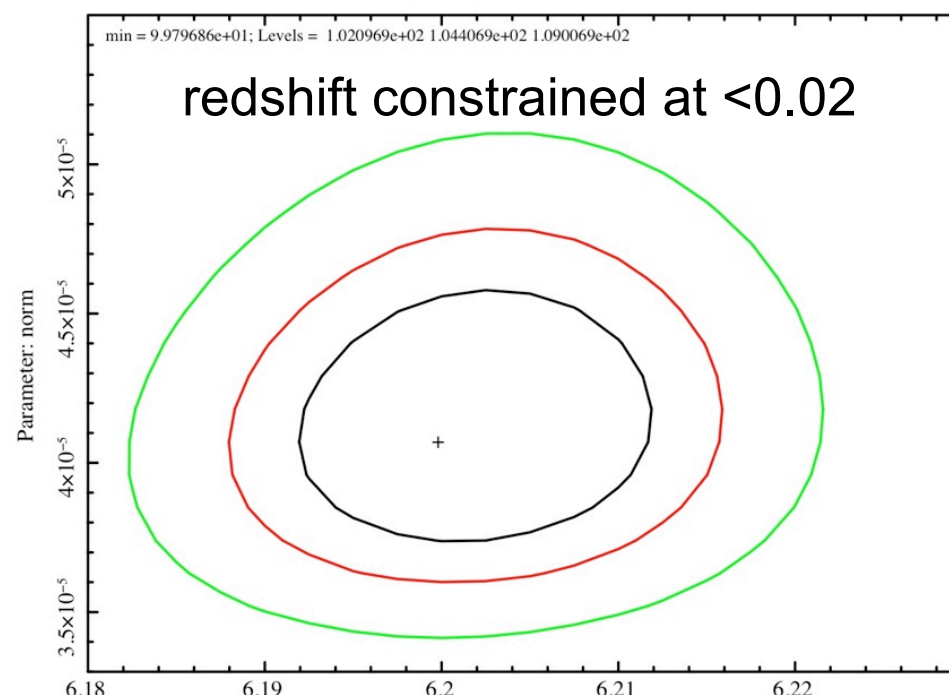
WISE: 3.6~19.5 (not enough?)
LOFAR: 0.8 mJy at 120 MHz (= 0.1 mJy at 1.4 GHz)
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IXO observations of $z \sim 6$ QSOs

20ks, logNH=23.6, $z=6.2$, $P=2e-14$



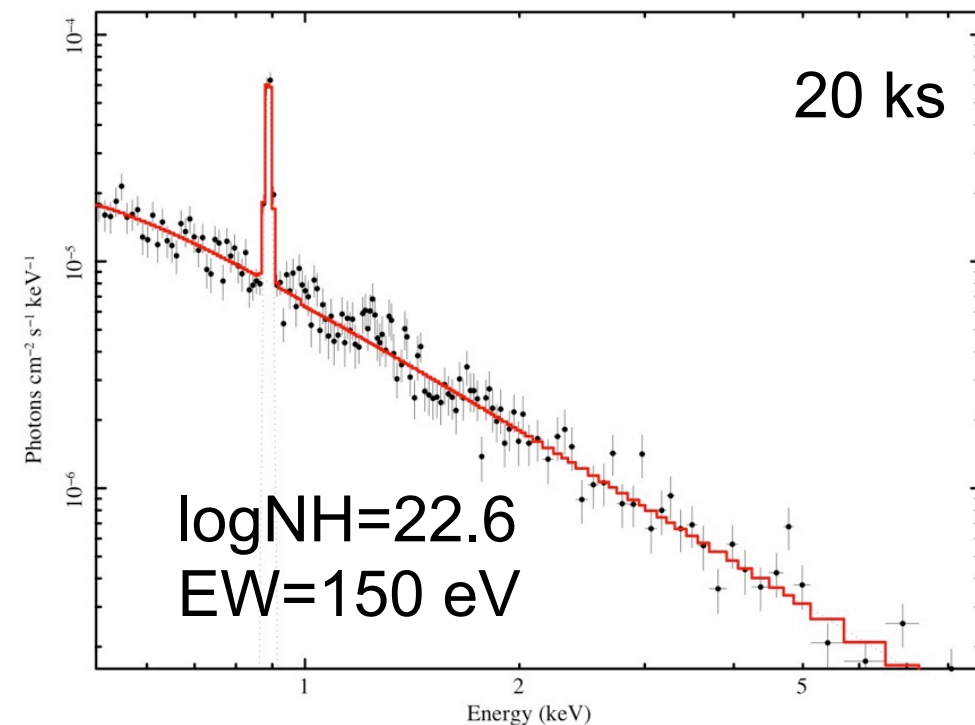
Confidence contours: Chi-Squared



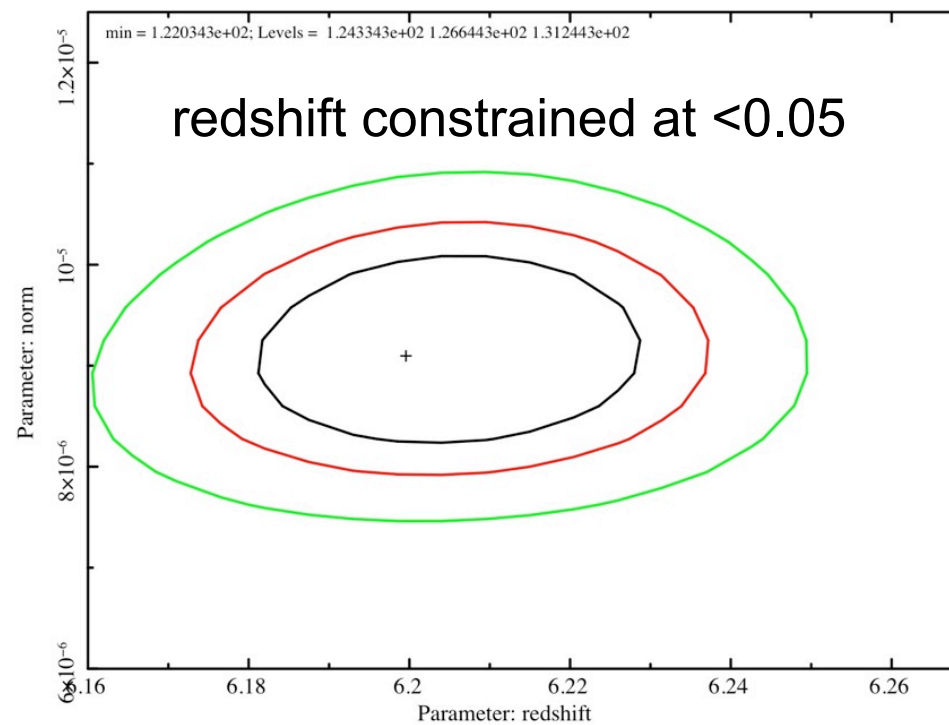
**X-ray redshift
determination feasible
with reasonable
exposure times**

**BUT you need to know
where to point IXO !**

20ks, logNH=22.6, $z=6.2$, $P(2.10)=2e-114$



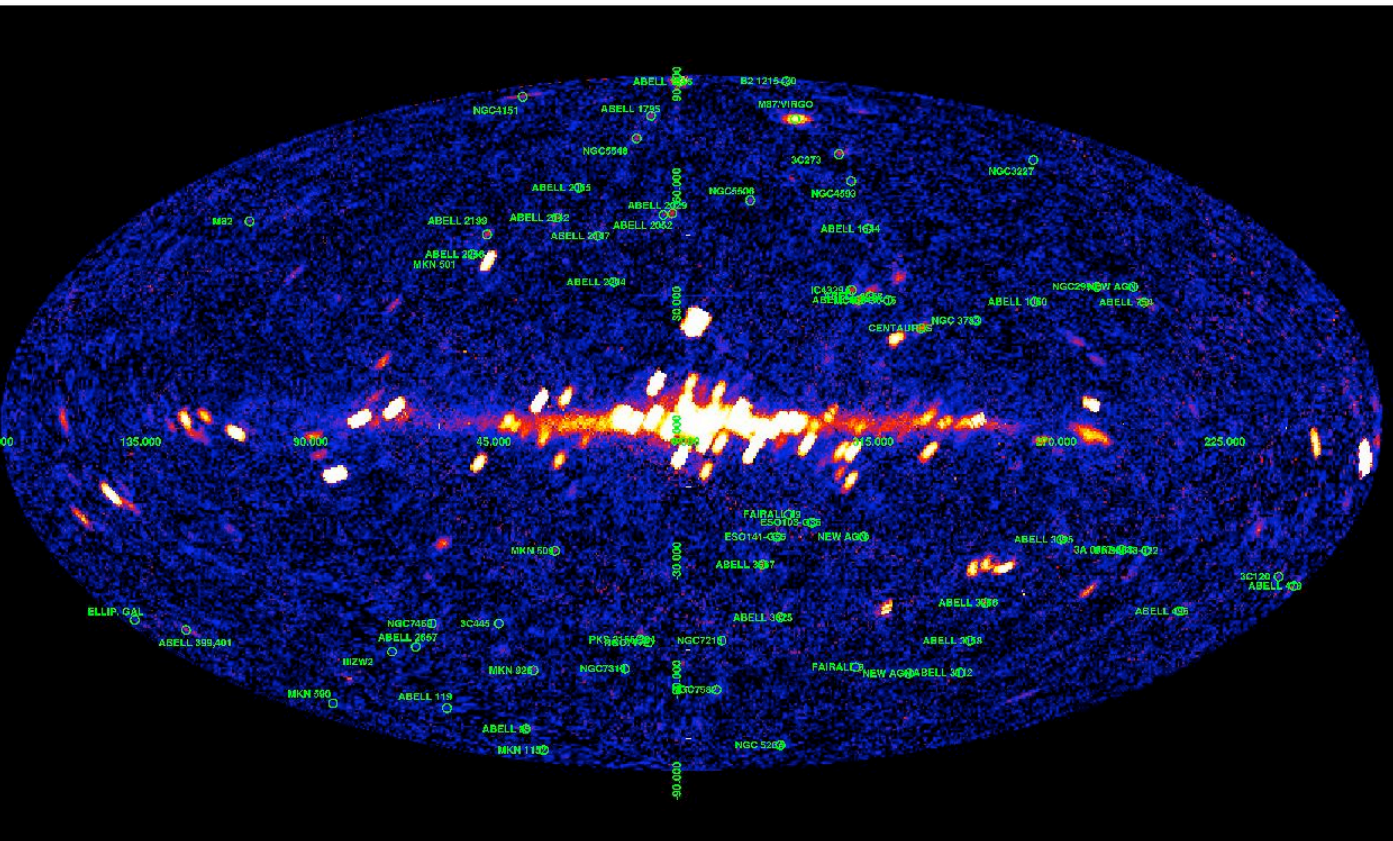
Confidence contours: Chi-Squared



[response matrix: ixo-glass-wfi-alpp-20100625.rsp](#)

IXO Science Meeting (14-16 March 2011, Rome/CNR)

2-10 keV all sky survey

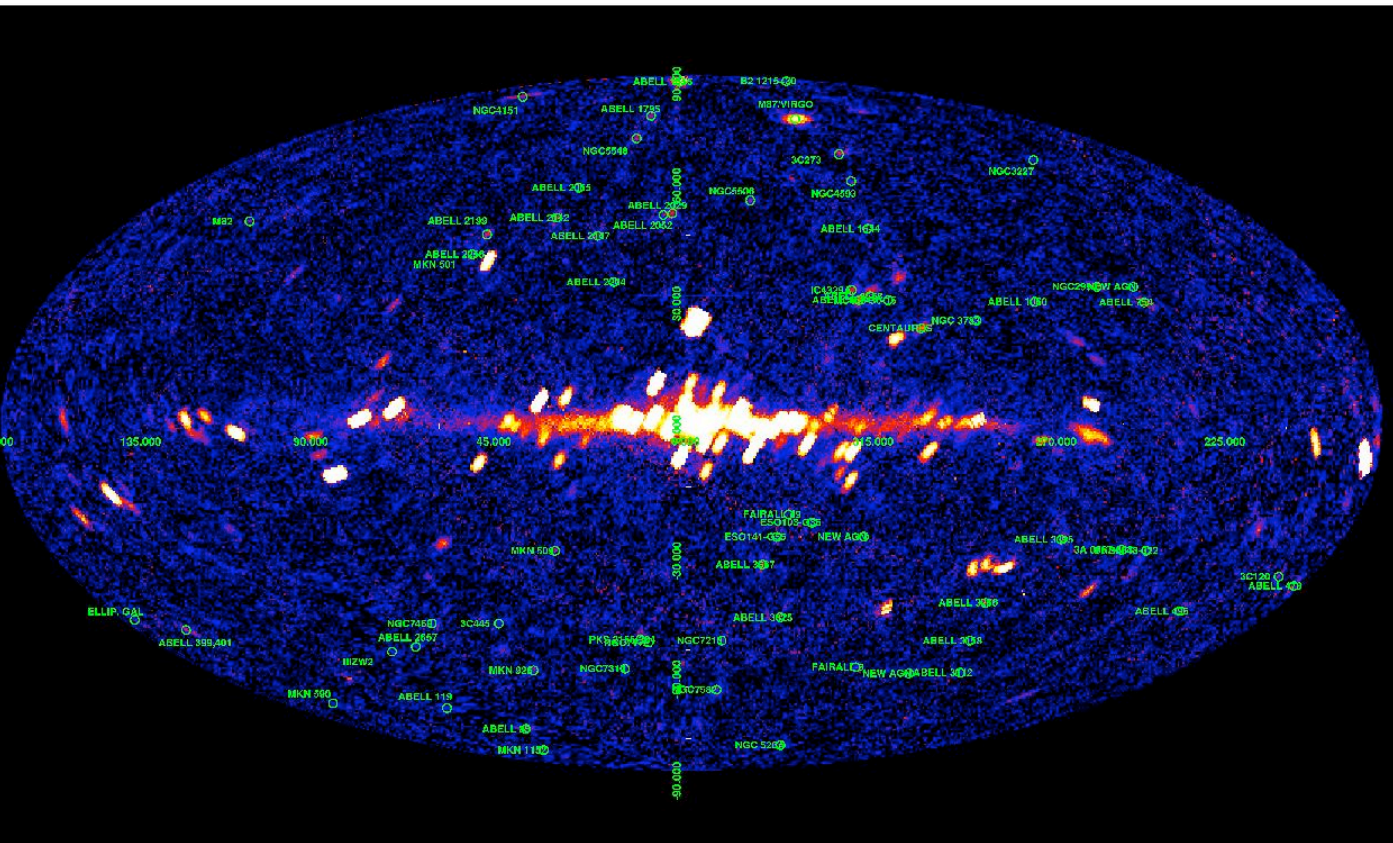


30-years old 2-10 keV HEAO-1 all sky map

36 AGN (Piccinotti et al. 1982)
at flux $> 3.1 \times 10^{-11}$ cgs

(+clusters of galaxies, LMC, SMC, M82..)

2-10 keV all sky survey



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PREDICTIONS for eROSITA survey:

1) assuming a limiting flux of $1e-13$ cgs

2) using Gilli+2007 model

~130.000 over the extragalactic sky !
with a clear and uniform selection function

N.B.: (as a comparison)

~5500 pointlike sources ($|b| > 20^\circ$) in the
2XMM catalog (Watson et al. 2009) with
flux $> 1e-13$ cgs (over a smaller area, very
different/complicate selection)

“OBSCURATION” SPACE

(see Reynolds and Matt talks tomorrow)

67% unobscured ($NH < 22$)

0.2% CT
($NH > 24$)
220 obj!!

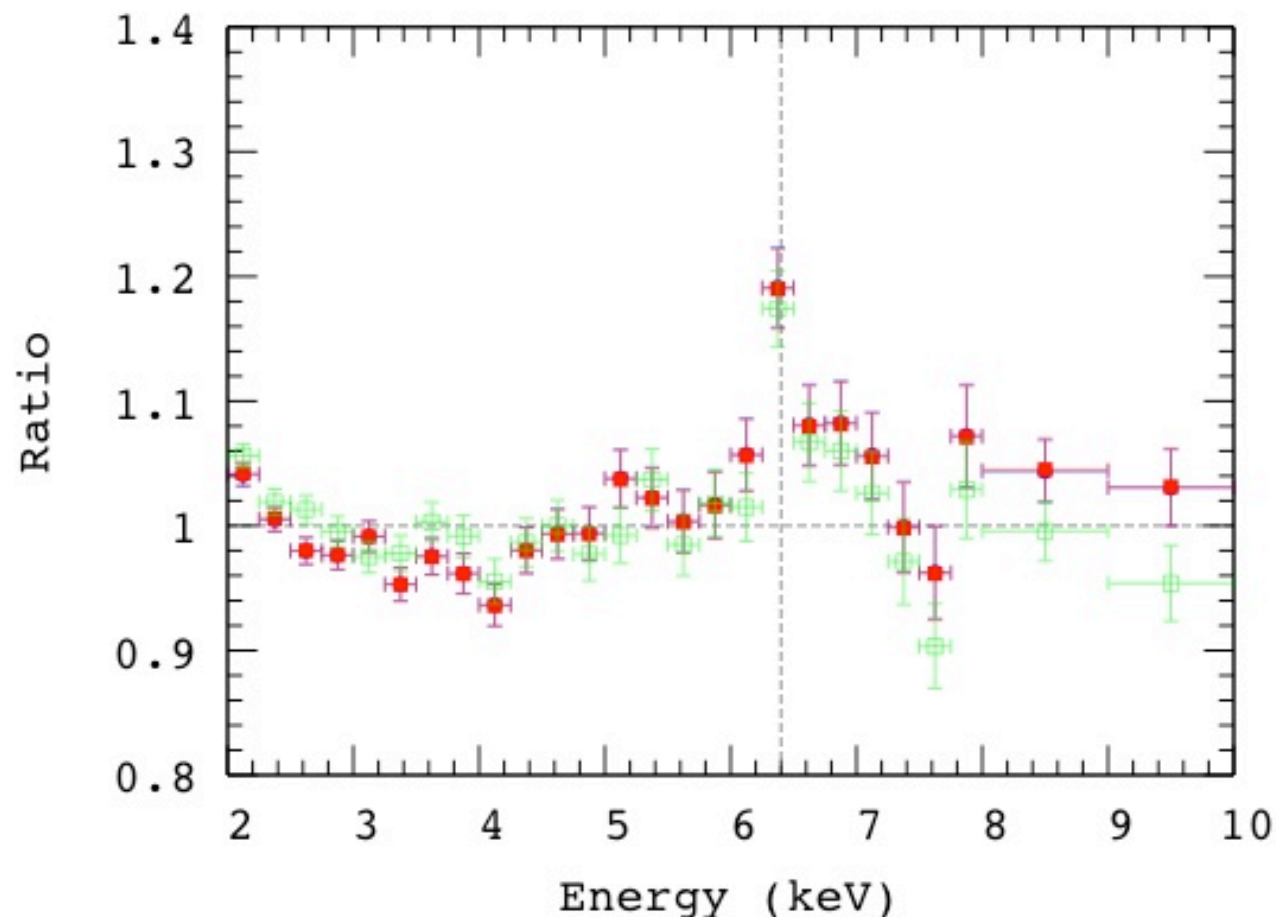
33% Compton Thin
($NH = 22-24$)

130.000
2-10 keV selected AGN
at $f > 1e-13$ cgs

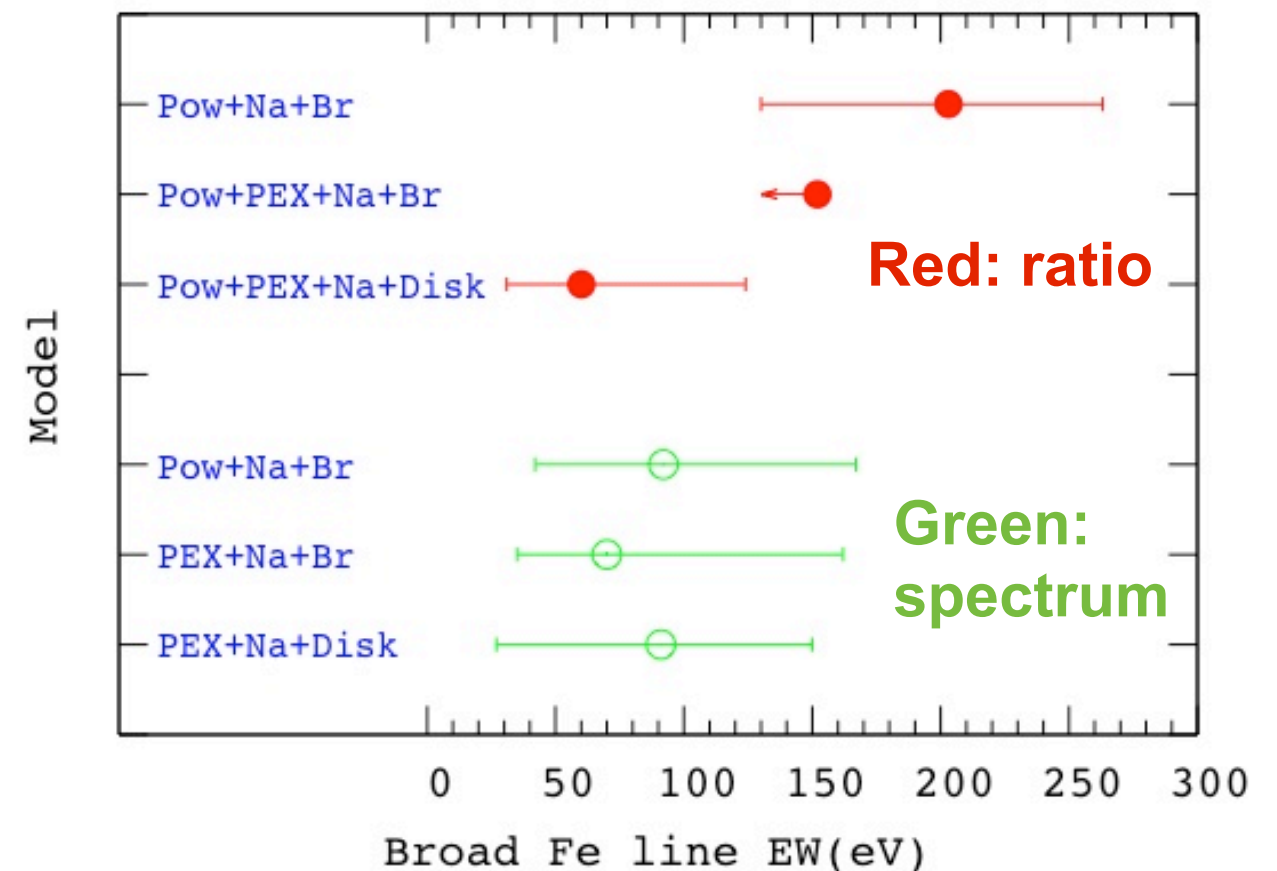
(digression/advertisement)

stacking analysis of 2XMM sample

- stacking of **~250** 2XMM catalog sources (selected from Watson+2009) & redshifts from NED (Chaudhary et al. 2010, **Chaudhary, MB et al. 2011, in prep**); additional threshold in number of counts; total of **~200.000 counts** in the 2-10 keV band



Different methods and approaches have been tested (**averaged ratios**, **averaged spectrum** etc.)



Results tested against different modeling (w and w/o pexrav, broad vs. diskline) and continuum simulations

similar results **Brusa+2011** CDFs
(see debate in literature on ubiquity of relativistic line in stacked spectra e.g. Streblyanska+05 vs. Corral+08)

“OBSCURATION” SPACE

(see Reynolds and Matt talks tomorrow)

0.2% CT
($N_H > 24$)
220 obj!!

67% unobscured ($N_H < 22$)

33% Compton Thin
($N_H = 22-24$)

130.000

2-10 keV selected AGN
at $f > 1e-13$ cgs

33% at $z < 0.3$
(complete for $L_x > 42$
at ~ 300 Mpc)

20% at $z > 1.3$
 **$L_x > 45$ (> 3000 with
 $N_H > 23$!)**

(feedback laboratories,
synergies with ALMA,
outflows studies - King)

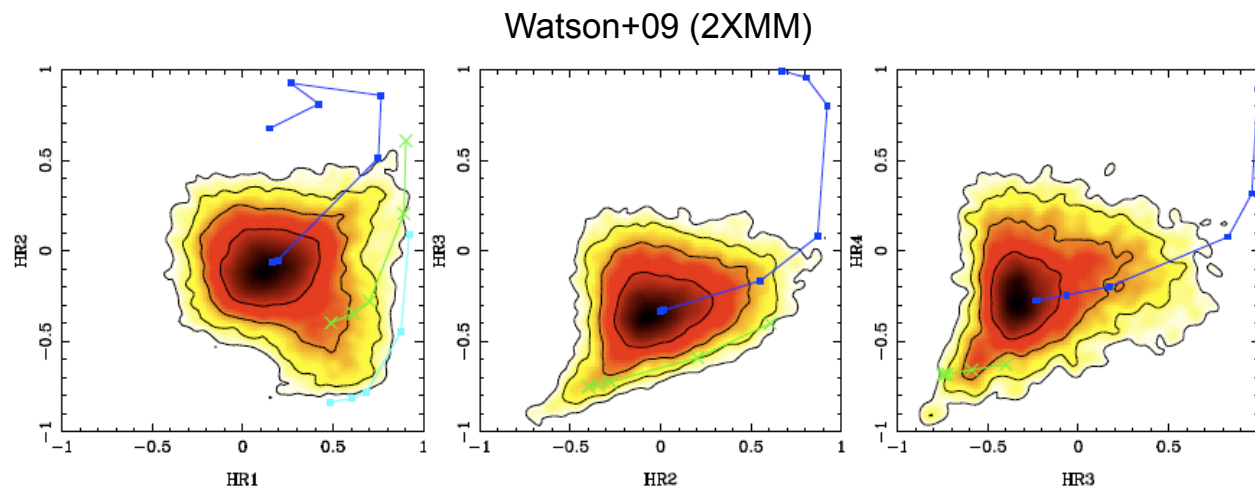
33% at $z \sim 0.5$
($0.3 < z < 0.7$)
 $L_x > 44$

20% at $z \sim 1$ ($0.7 < z < 1.3$)

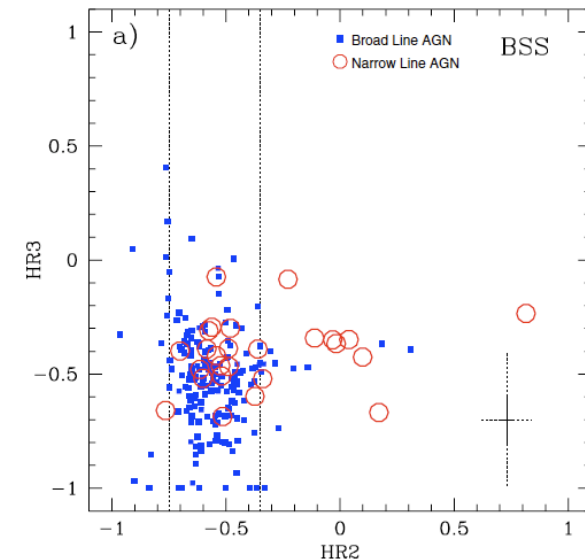
REDSHIFT SPACE

Picking up most obscured/interesting sources

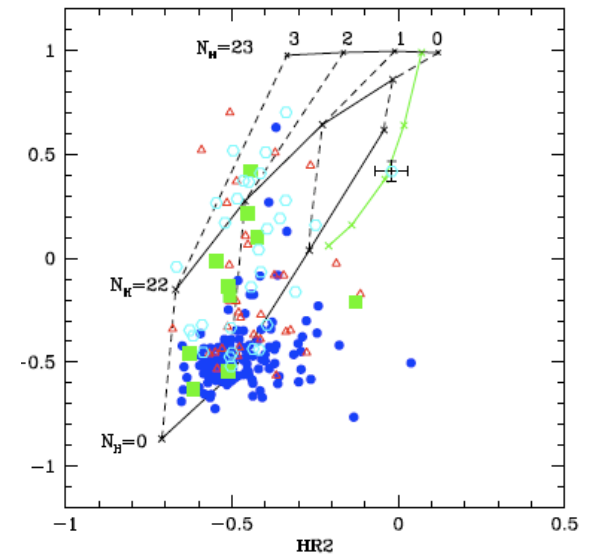
1) Hardness ratios



Della Ceca+04
(XMM-BSS)

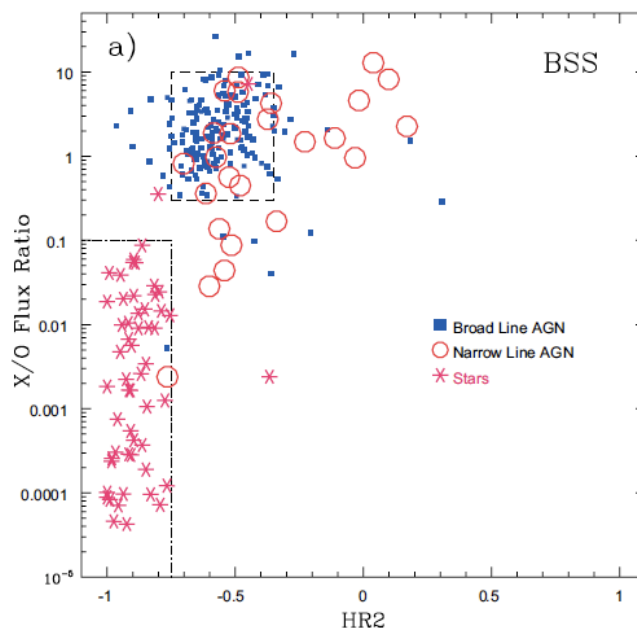


Cappelluti et al. 2009
(COSMOS)

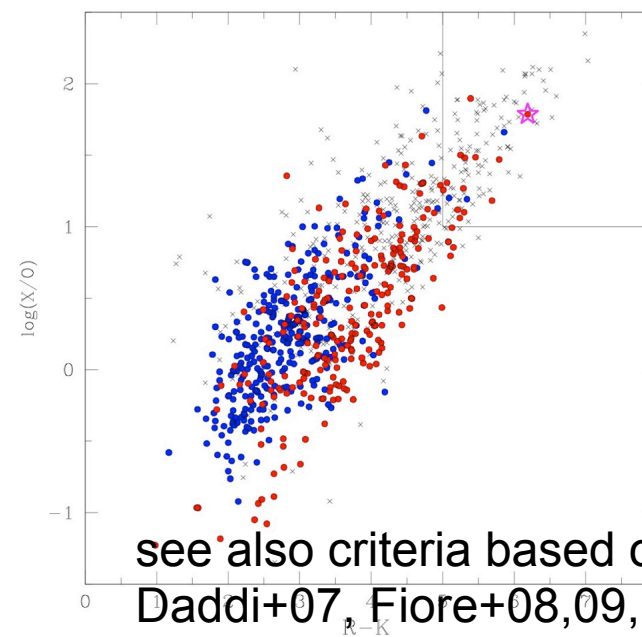


2) Cross-correlation with other lambda catalogs

X/O ratio vs. HR
Della Ceca+04 (XMM-BSS)



X/O ratio vs. R-K
(Brusa et al. 2010)



most of these sources have been revealed (and will be revealed with eROSITA) with low counting statistics (20-100 cts)

Require extensive use of VO and large astronomical databases

see also criteria based on IR data presented and explored by Daddi+07, Fiore+08,09, Alexander+10, Treister+09, Feruglio+11 etc... highly contaminated...

Conclusions

- 1) eROSITA will provide (among others) the first all sky survey 2-10 keV after HEAO-1 at considerable (10^{-13} cgs) depth, and will detect sizable samples of high- z QSO ($z > 3$)
- 2) IXO can provide **UNIQUE** spectral characterization of well defined/selected sample of eROSITA sources, e.g.:
 - a) obscured $z=1-3$ luminous quasars, i.e. signposts of galaxy/AGN evolution
 - b) first accreting SMBHs at $z > 3-6$

eROSITA contribution: single out the best candidates (X-ray detection is the smoking gun)
IXO contribution: characterizing spectral parameters, redshifts and spin (physics)
- 3) While waiting for IXO... Broad/relativistic lines studies *can* be pushed to fainter fluxes with stacking (**Literature results differ by one order of magnitude**); broad component *needed*, but $EW < 200$ eV
- 4) eROSITA still to be launched... we are happy IXO will fly in >10 years!

QSO2 signposts of major events

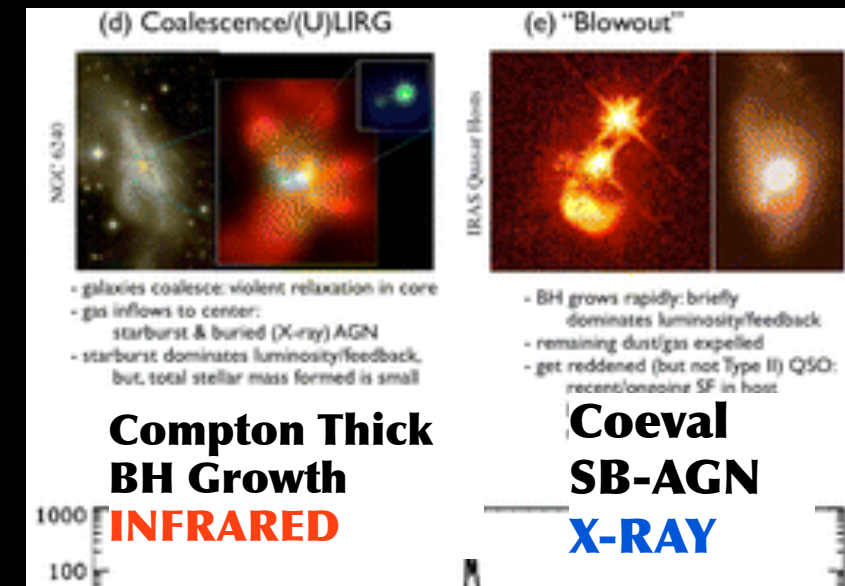
Most luminous, obscured X-ray selected sources are **redder**

--> effect of **relative contribution of AGN and host** or **feedback** more efficient to stop star formation, or **dusty environment**?

Very short phase (<< 1 Gyr): need larger brighter samples (RARE OBJECTS!!)

Sources like XID 2028 **within the limit of the eROSITA all sky!**

From XRB models: expected 0.2/deg² objects with $L_x > 45$, $N_H = 23-26$, $z = 1-3$, i.e. **3600** in the all sky hard eROSITA survey (likely **upper** limit, XRB models overpredict obscured AGN fraction at the highest luminosities, Brusa et al. 2010)



Physics laboratory for the AGN-galaxy coevolution models, BUT direct evidence of feedback from AGN at $z \sim 1-2$ not yet found!

Ideal targets for **ALMA** / **WFC3** / **X-shooter** / **JWST** follow-up and **deep IR** spectroscopy
--> detect nucleus in the IR and molecular outflows in the millimeter!

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survey (likely **upper limit**

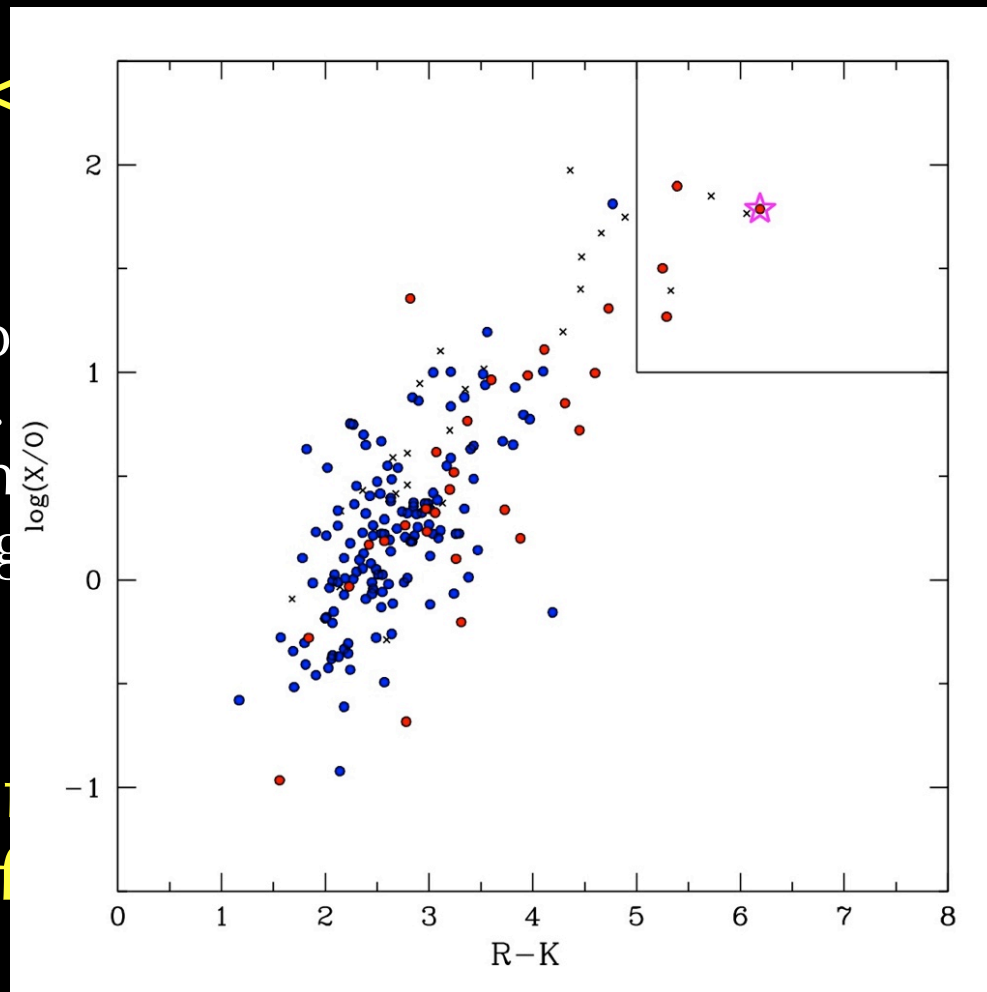
AGN fraction at the high

Physics laboratory

direct evidence of

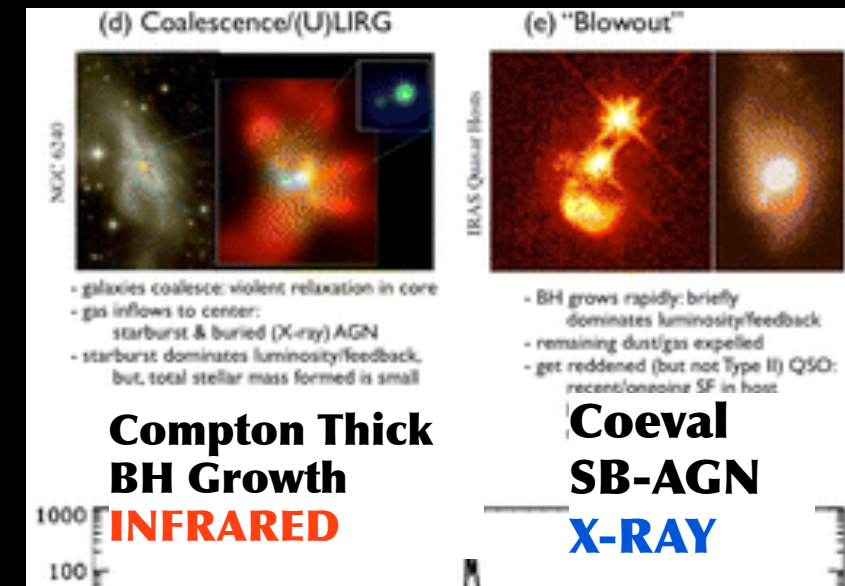
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Examples (RARE OBJECTS!!)

ky!



models, BUT

not yet found!